**Field Test Evaluation of**
**Uranium In-Situ Recovery (ISR) Contaminant Fate and Transport Supporting Development of Permit Requirements Protective of Groundwater Down-Gradient of ISR Wellfields**

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## Introduction

The work conducted under this Regional Applied Research Effort (RARE) supported the Region 8 Underground Injection Control (UIC) Program in preparing draft injection well permit requirements for the proposed Dewey Burdock uranium in-situ recovery (ISR) site located in southwest South Dakota.

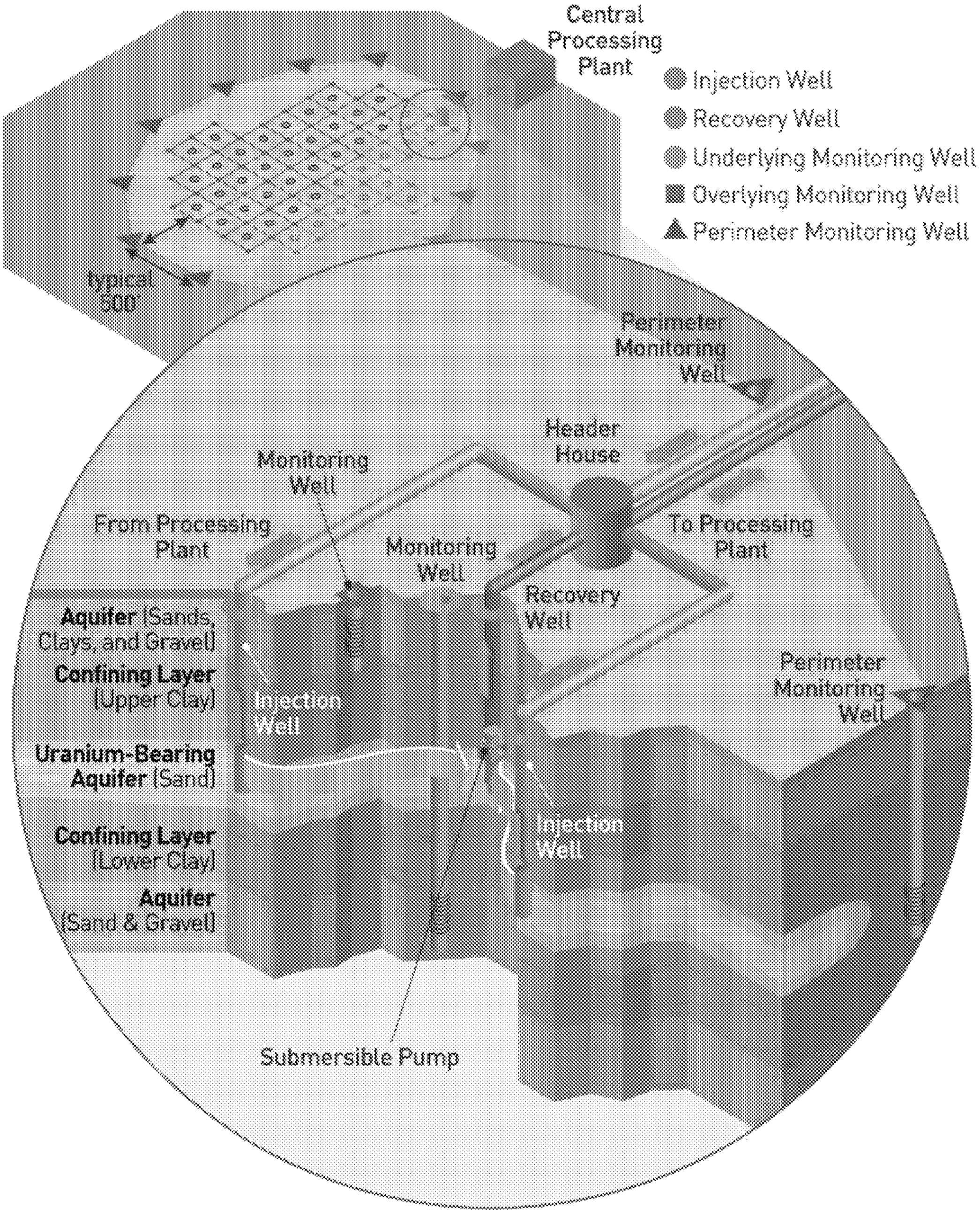
The 2014 RARE project builds upon work completed under a 2010 RARE project, which performed reactive transport modeling of ISR contaminants to evaluate mitigation capability of the downgradient ore-bearing aquifer to prevent contaminant migration across the down-gradient aquifer exemption boundary.

For the 2014 RARE, the Los Alamos National Laboratory (LANL) performed injection tests at the Cameco Resources Smith Ranch ISR site in Wyoming to field test contaminant transport and mitigation potential in the down-gradient ore-bearing aquifer. This field study demonstrated the ability of the down-gradient ore-bearing aquifer to attenuate ISR contaminants as they flow downgradient.

## The ISR Process

- During uranium recovery, lixiviant is injected in wellfields to mobilize uranium through the ore-bearing portions of an underground source of drinking water (USDW).
- The role of the Region 8 UIC Program is to regulate the injection activities and evaluate the merits of an aquifer exemption (AE) of the uranium-ore-bearing portions of the injection zone USDW.
- After the uranium recovery process is complete, the NRC (or Agreement State) license and state mining permit conditions require the injection zone groundwater in the ISR wellfield to be restored to pre-mining conditions.
- Often Alternative Concentration Limits (ACLs) must be established when pre-mining conditions cannot be regained for some constituents.
- After aquifer restoration is complete and the natural groundwater gradient is re-established, the UIC regulations prohibit ISR contaminants from crossing the AE boundary in concentrations above pre-mining conditions.

# The In Situ Uranium Recovery Process




Injection wells ● pump a solution of native ground water, usually mixed with sodium bicarbonate and oxygen, into the aquifer (ground water) containing uranium ore. The solution dissolves the uranium from the deposit in the ground and is then pumped back to the surface through recovery wells ●, all controlled by the header house. From there, it is sent to the processing plant. Monitoring wells ● ■ ▲ are checked regularly to ensure that injection solution is not escaping from the wellfield. Confining layers keep ground water from moving from one aquifer to another.

*As of July 2016*

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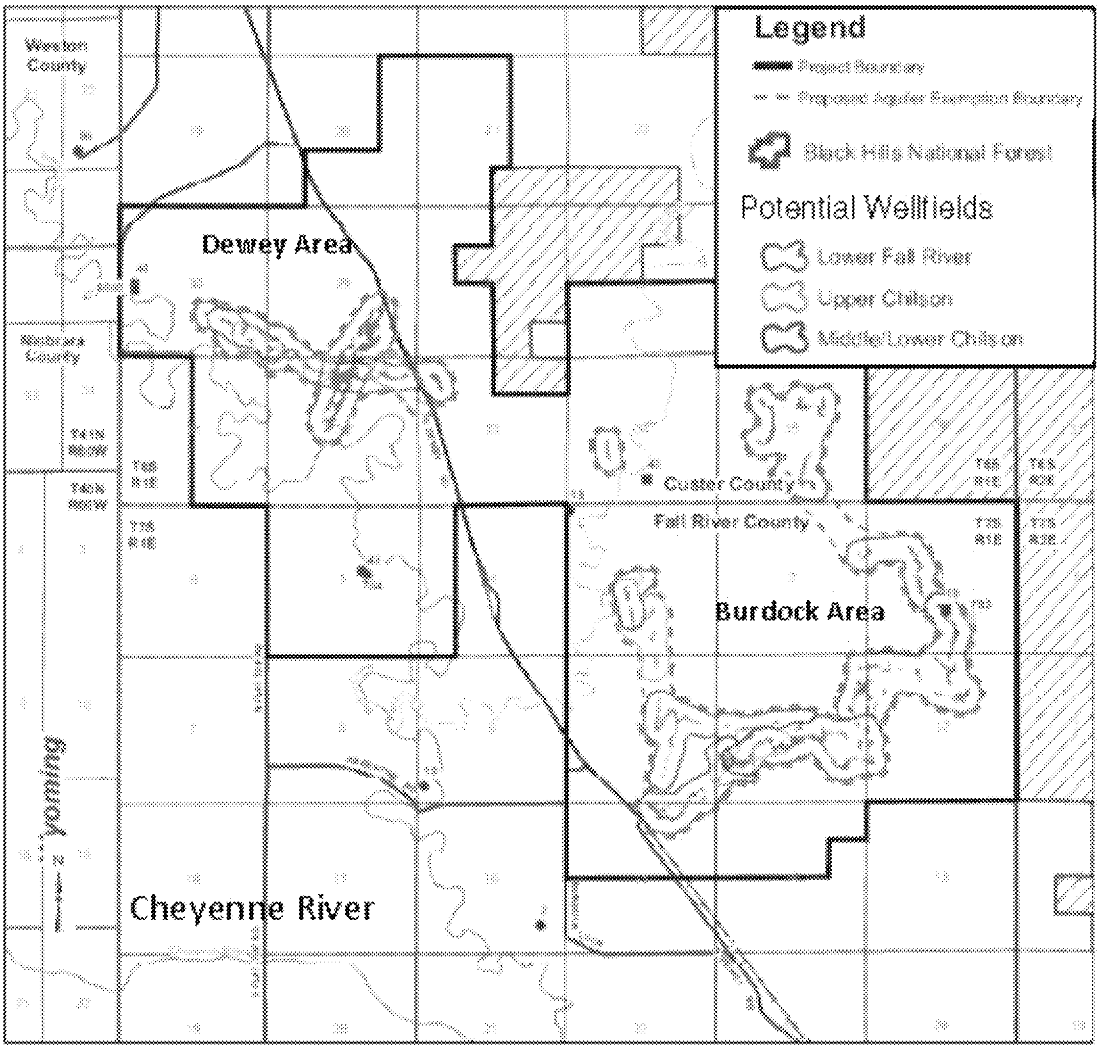
**Research Objectives**

- Evaluate the ability of the downgradient aquifer to geochemically attenuate ISR contaminant transport.
- Translate test results into predictions of down-gradient transport of problem constituents (in progress).

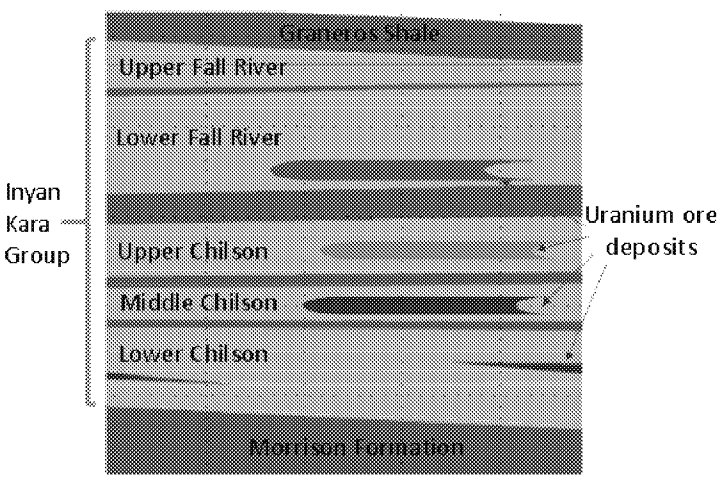
**The Permitting Challenge for the EPA UIC Program**

- The Dewey-Burdock UIC injection well permit is the first EPA permit to be issued for uranium ISR.
- Current industry practice is to assume the downgradient portion of the ore-bearing (injection zone) aquifer has adequate reduction geochemistry to attenuate any residual ISR contaminant concentrations to meet UIC regulations.
- However, current ISR permits do not require monitoring to verify that ISR contaminant concentrations are below pre-mining conditions at the AE boundary.
- The Region 8 UIC Program applied for RARE funding to test the likelihood for ISR contaminants to cross the AE boundary above pre-mining concentrations.

# Dewey Burdock Proposed ISR Wellfields




## Locations of Uranium Ore Deposits at the Dewey-Burdock Site



**Research Methods**

- Under a 2010 RARE project, the USGS developed a general conceptual model and 1D/2D reactive transport models (groundwater flow and geochemistry). The models simulated uranium roll-front formation, pre-ISR groundwater conditions, and simulations of uranium ISR, restoration, and long-term transport.
- The model was calibrated with pre-ISR core sample geochemistry and groundwater quality data.
- The 2014 RARE project involved injection/recovery field tests to examine the effect of reduced host rock on unrestored wellfield groundwater.
- The LANL conducted cross-hole tests involving injection of unrestored ore-zone groundwater spiked with tracers, Se and Mo to provide information on redox processes.

**Reactive Transport Modeling**
**Take Home Points**

- Downgradient reducing capacity is key.
- Pyrite is potentially the key to removing uranium (modeled reducing conditions).
- Calcite is potentially the key to buffering acidity
- With these minerals present, get an iron, sulfate, calcium, carbonate "plume."
- Increase in these elements depends on the amount of oxygen left in the mining zone.

**Reactive Transport Modeling**
**Conclusions**

- Reactive transport modeling provides a predictive tool that can assess downgradient geochemical changes post mining.
- Limited core data helps quantify pyrite with an "assumed" reducing capacity.
- Still need a better understanding of pyrite distribution (could be part of the monitoring well installation –get core while drilling monitoring wells).
- Need lab measurements to measure pyrite reducing capacity (column tests, batch sorption tests).

**Cross-Hole Injection/Recovery Tests**

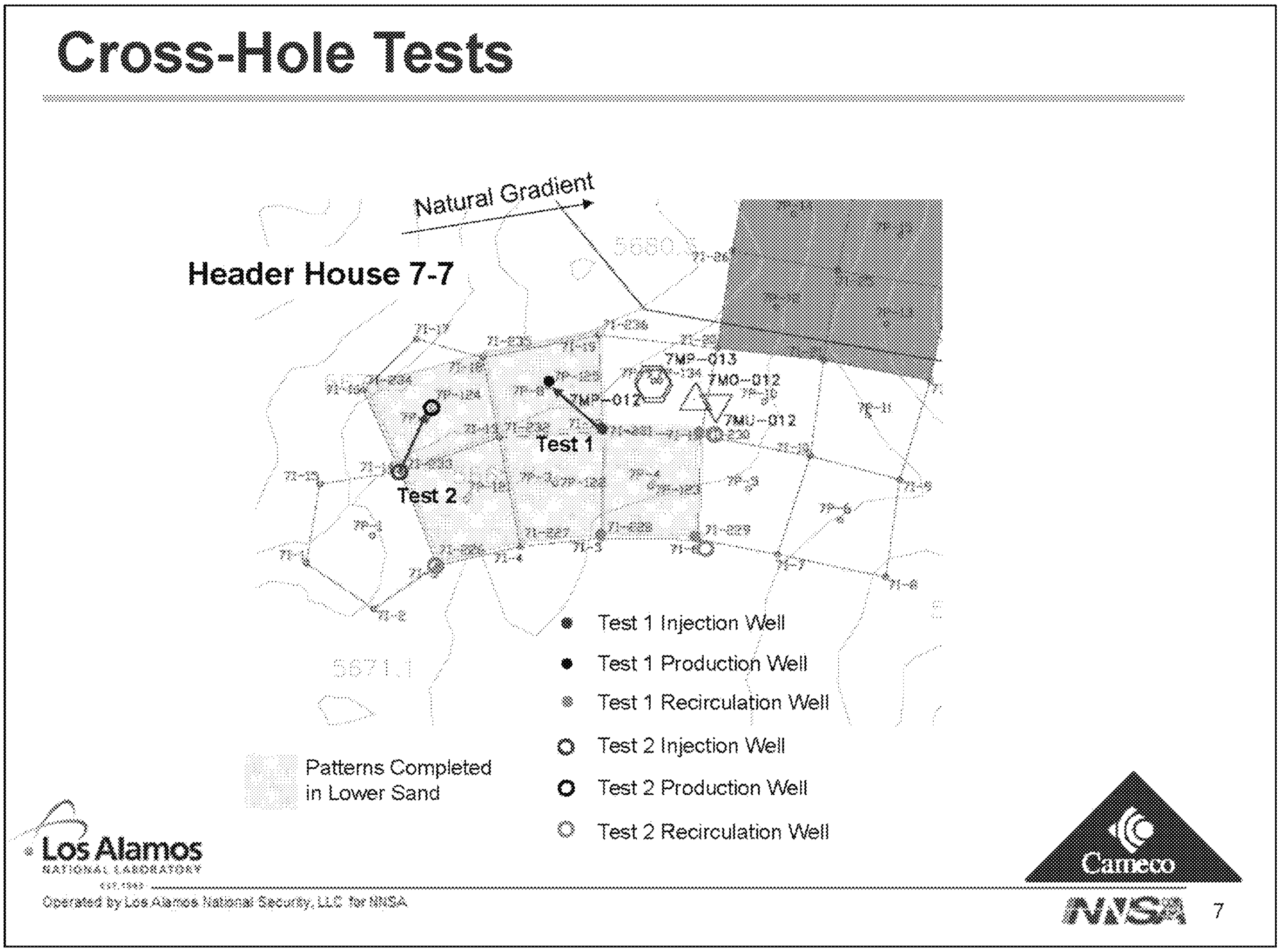
Two cross-hole injection/recovery tests were conducted in a pre-ISR wellfield using injection and production wells 70-80 feet apart. Unrestored post-mining ore-zone groundwater from another wellfield was used as the injectate spiked with additional constituents.

**First test:**

- **Conservative tracer**
- Se as Na2SeO4
- Mo as Na2MoO4
- V as NaVO3.H2O
- Production well pumped for ~107 days at ~10 gpm

**Second test:**

- Conservative tracers injected at beginning (results not presented)
- ~61 days of MP-423 water injection at ~3 gpm
- Production well pumped for almost 1 year at ~10 gpm



### Key Cross-Hole Test Results

- Both Se and Mo appear to be reduced over time scales of weeks and distance of ~75 ft based on recoveries relative to bromide and also isotope measurements.
- Even using unrestored water, more than 65% of U was not recovered in a year in test with no vanadate (projected to be 55% in 3 years).
- Vanadate quite effective at immobilizing U, but unclear how easy it would be to distribute in aquifer (does not transport conservatively).
- Modeling and uranium and other isotope data (still pending) will help identify what processes were involved in uranium immobilization.

In general, results suggest that down-gradient aquifer has significant attenuation capacity for both Se and U at a typical ISR site.

### Conclusions

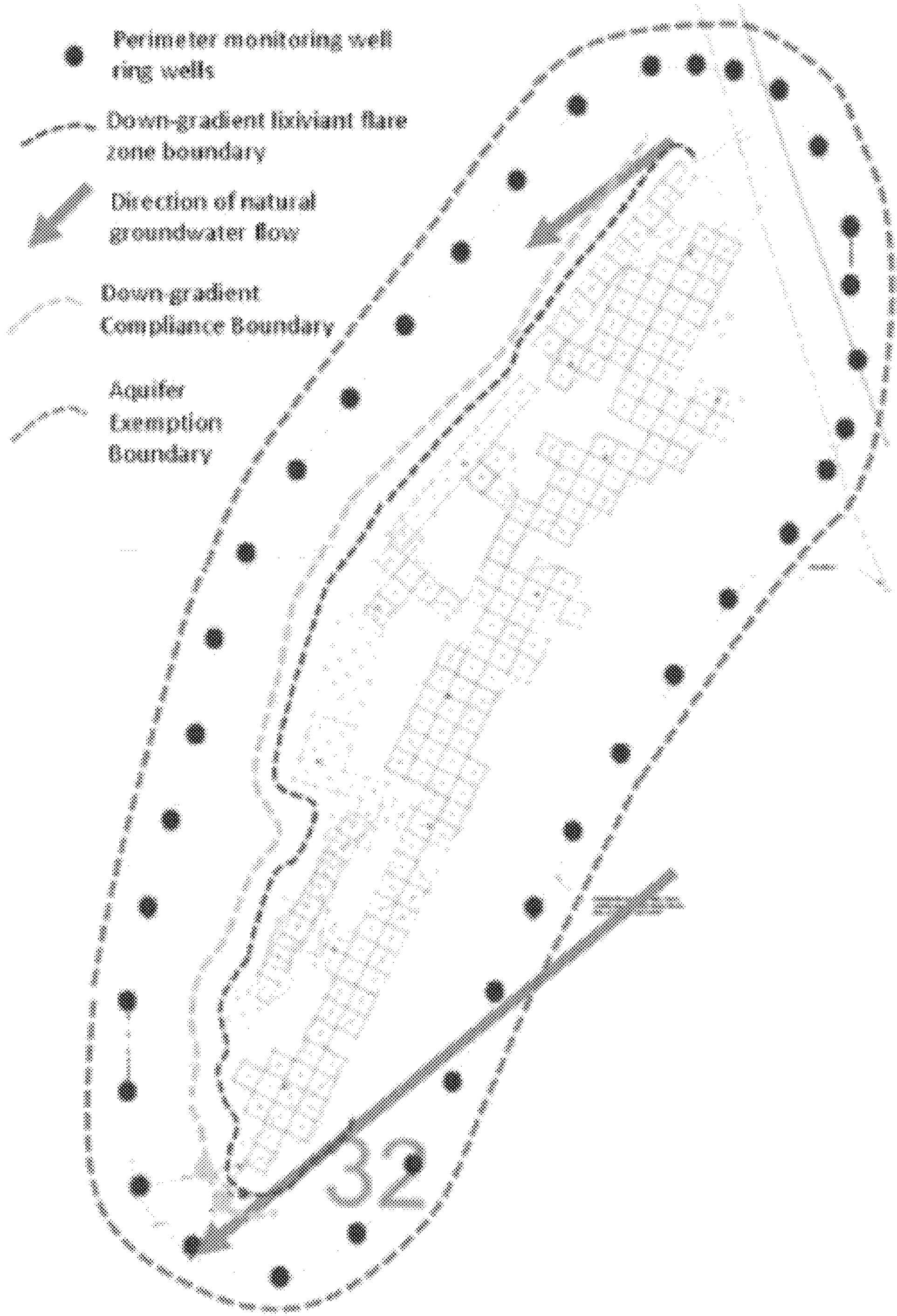
The Region 8 UIC Program concluded that the reactive transport modeling results indicated that post restoration monitoring was warranted to verify that ISR contaminants did not cross the AE boundary above pre-ISR concentrations.

The UIC permit includes a number of requirements new to the ISR industry:

- Post-restoration monitoring
- Additional monitoring of excursions
- Core collections during drilling of monitoring wells.
- Laboratory column testing using core to determine the attenuation capacity of the down-gradient injection zone aquifer.

The LANL field test results helped inform viable locations of a down-gradient compliance boundary for monitoring concentrations of ISR contaminants in the injection-zone aquifer down-gradient of the restored wellfield.

# Post-Restoration Monitoring



## References

Johnson, R.H.[1], Morrison, J.M.[2], Gallegos, T.J.[2], and Diehl, S.F.[2], 2012, Using groundwater and solid-phase geochemistry for reactive transport modeling at the proposed Dewey Burdock uranium in-situ recovery site, Edgemont, South Dakota: presentation at Region 8 US EPA, April 11, 2012, Denver, CO. Available at http://crustal.usgs.gov/projects/UREP/5-Reactive-transport-modeling-Dewey-Burdock-Johnson-final.pdf

[1]Formerly at USGS
[2]USGS

Reimus, P.[1], Clay, J.[2], Perkins, G.[1], Brown, S.[3], and Williams, K.[1], 2017, Cross-Hole Evaluation of Uranium and Selenium Natural Attenuation after ISR Mining:
presentation at the 2017 National Mining Association Uranium Recovery Workshop, June 6, 2017, Denver, CO.
Available at http://nma.org/wp-content/uploads/2017/06/NMA_2017_Clay%5E0Reimus_R1Ver1.01.pdf

[1]Los Alamos National Laboratory
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